NEW APPROACHES
IN WARNING BEACON DESIGN
TO IMPROVE WORKER SAFETY
(GRANT NO. R01OH010165)

Impacts of Warning Light Intensity and Flash Patterns on Driver Response

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Background

- The presence of multiple, uncoordinated warning lights can create "visual chaos" for drivers instead of "visual information," possibly compromising worker safety
- Objective: Build on previous research focused on warning light performance
  - Intensity for detection/ glare prevention
  - Temporal modulation for closure detection
  - Coordination of multiple warning lights

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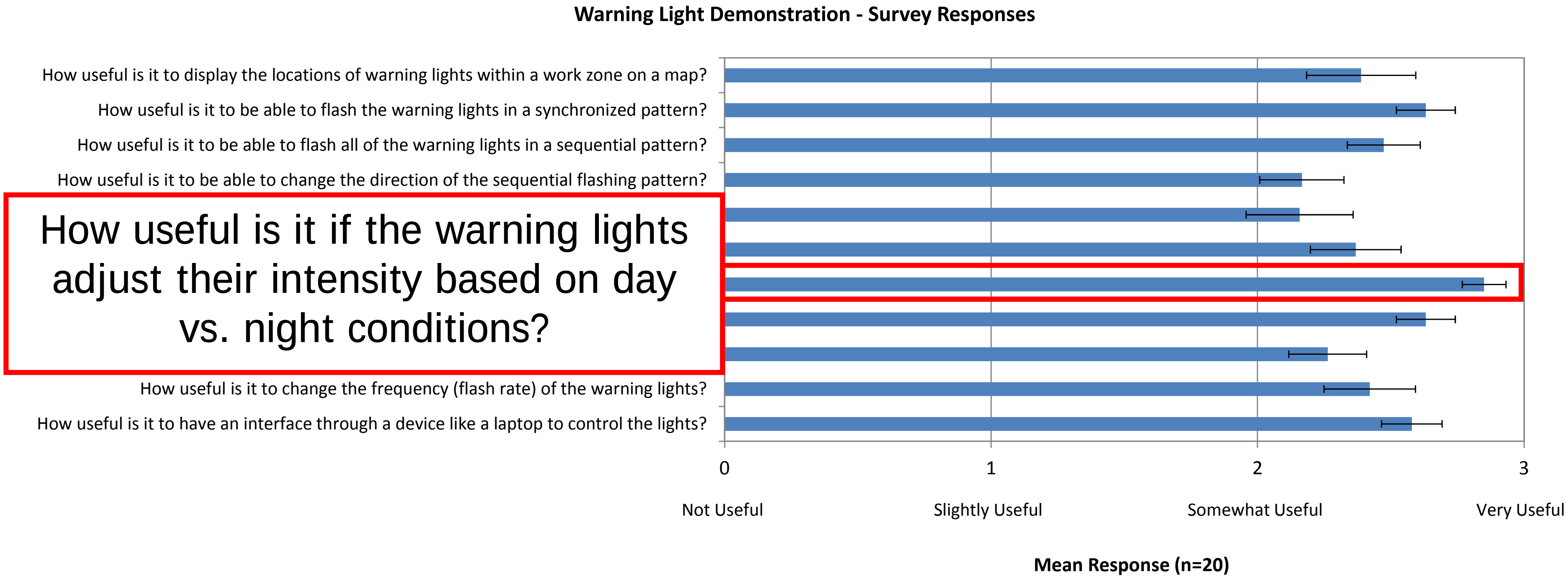
A Roadway Incident Scene Today

Demonstration of Prototype Warning Lights



- 20+ observers from New York State Department of Transportation, New York State Thruway Authority and Federal Highway Administration provided feedback about the prototype warning lights

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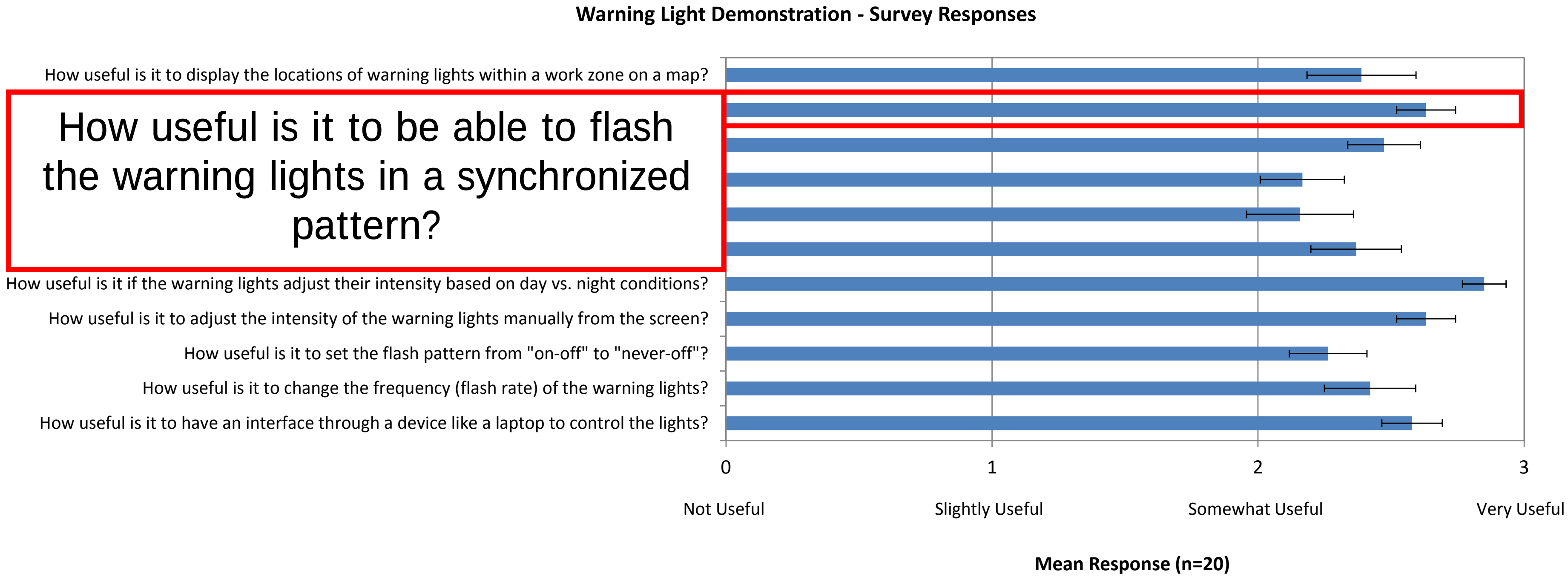
Demonstration of Prototype Warning Lights



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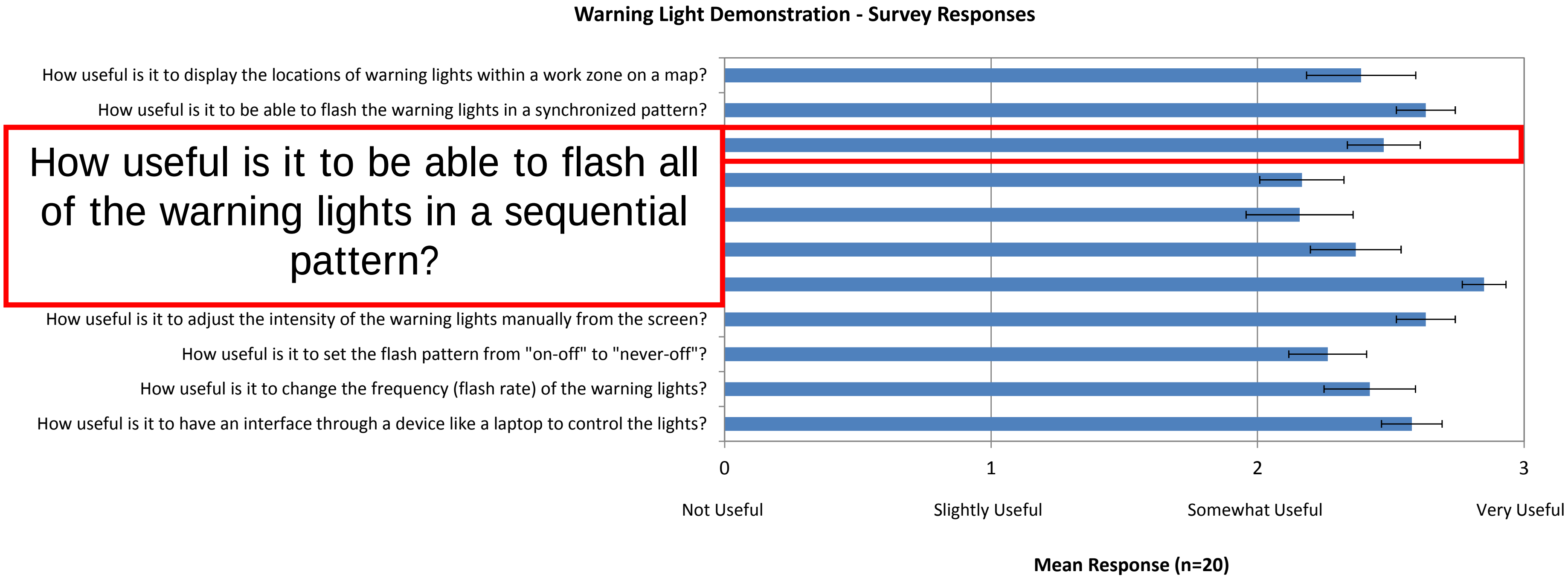

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A Roadway Incident Scene

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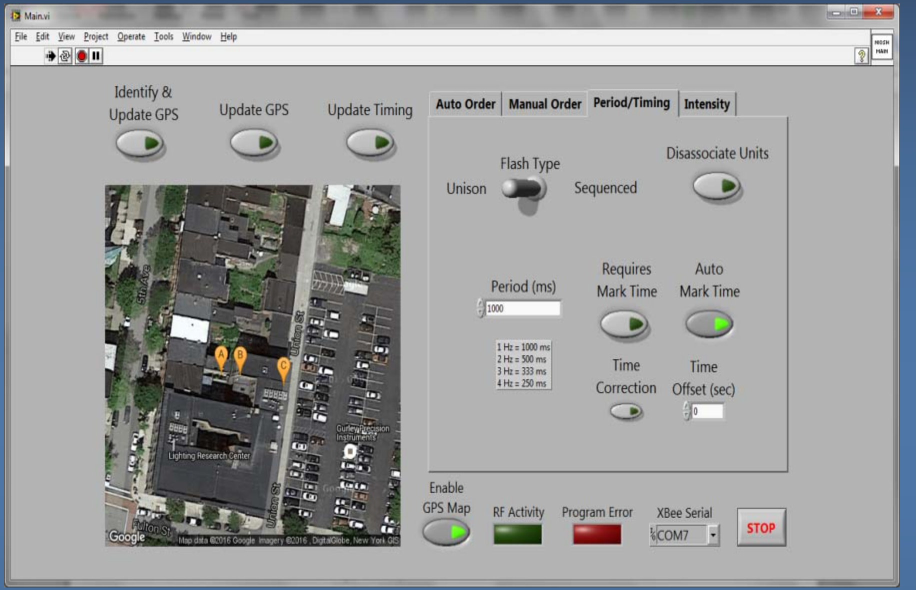
Prototype Warning Lights

- A set of prototype warning lights has been developed along with software for monitoring and control
  - Global positioning system (GPS) sensors and map display for relative position
  - Radio transmitters and receivers for wireless control
  - LED light source and drivers for intensity control based on ambient conditions
  - Ability to implement synchronized or sequential flash patterns of multiple warning lights based on location, and to adjust intensity and flash frequency

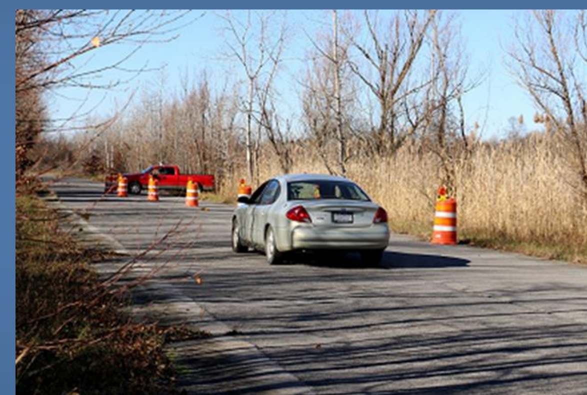


Experimental Questions

- Does a high-intensity warning light at the entrance to a lane diversion help drivers navigate through a road constriction?
- Can synchronized or sequential flashing patterns help drivers safely navigate through the road constriction?
- What is the optimal intensity for multiple warning lights during daytime and nighttime to convey veridical visual information to drivers about lane diversions through the constriction?

Experimental Conditions

- Multiple prototype LED barricade lights mounted on traffic drums set up to create a mock-up work zone
- Lane diversion maneuver required in one direction
- Experiment conducted on a closed, dead-end roadway both day and night



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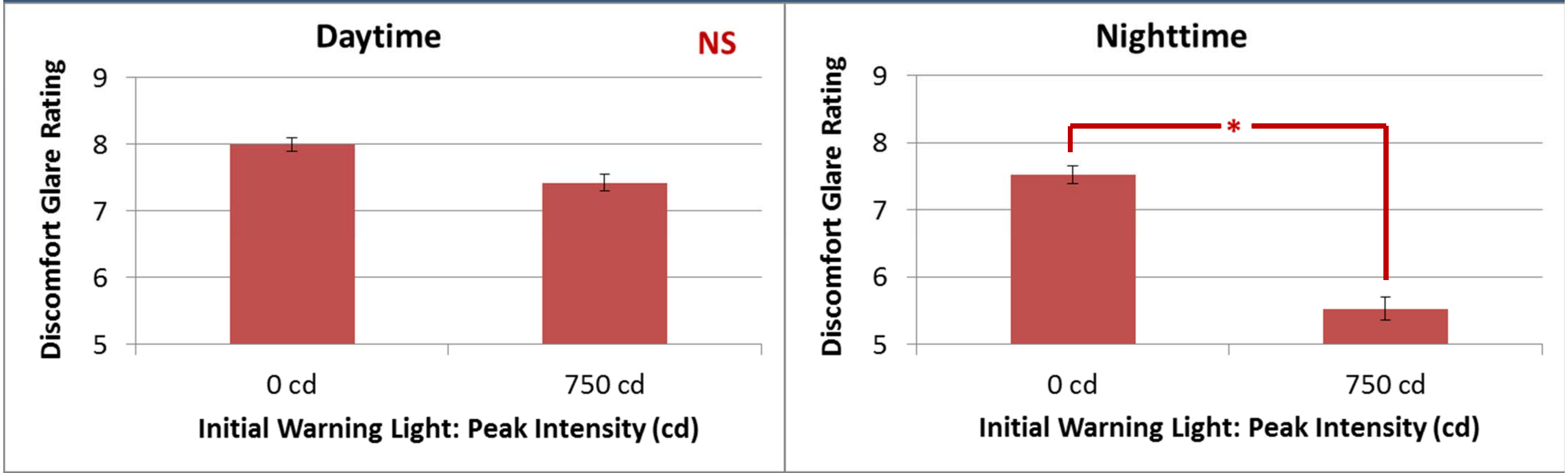
Experimental Conditions

- Warning light intensity: 7.5-250 cd (day), 2.5-75 cd (night)
- Initial warning light: 750 cd, 0 cd (off)
- Driving maneuver: lane change, no lane change

- Flash patterns: random, synchronized, sequential
- Twelve experimental subjects: licensed drivers with 20/30 acuity or better and normal color vision
- Outcome measures:
  - Subjective ratings of glare, ease of driving, accuracy of navigation, and perceptions of how quickly subjects drove through multiple warning lights
  - Driving speed within the road constriction

Results: Impact of a High-Intensity Initial Warning Light



- Daytime: The presence of the high-intensity initial warning light was judged as “satisfactory” by subjects
- Nighttime: Discomfort glare from the high-intensity initial warning light approached “just permissible”

9: unnoticeable glare
8
7: satisfactory
6
5: just permissible
4
3: disturbing
2
1: unbearable

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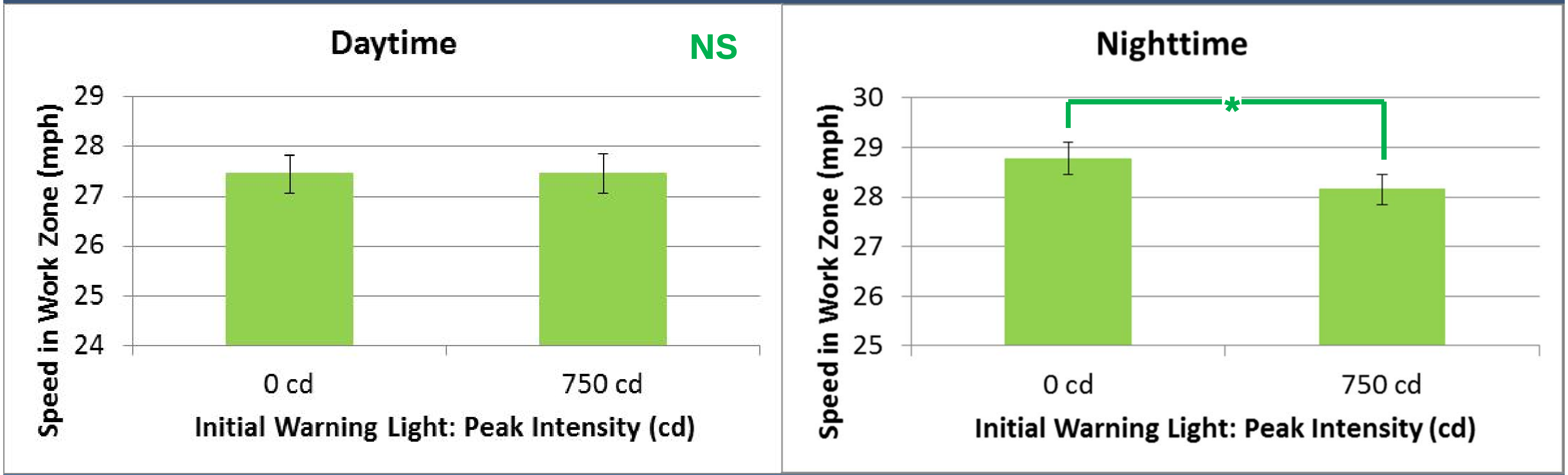
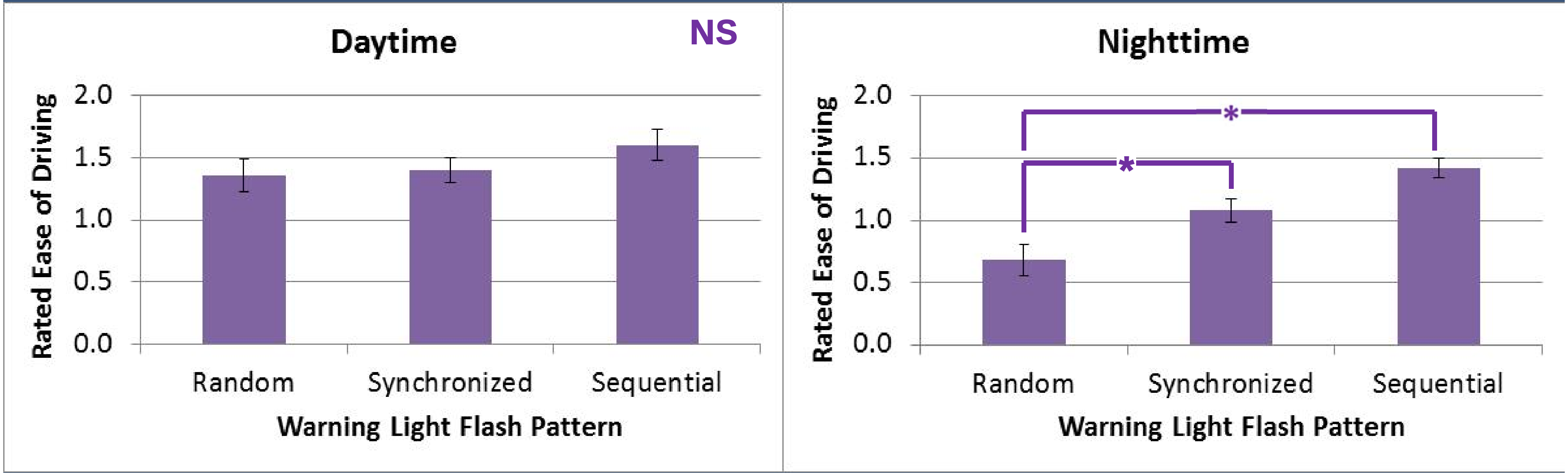
Results: Impact of a High-Intensity Initial Warning Light (cont'd.)



- Daytime: The presence of the high-intensity initial warning light had no impact on speed in the work zone / incident scene
- Nighttime: Driving speed was slower in the work zone / incident scene with a high-intensity initial warning light (probably caused by glare)

Results: Impact of Flash Pattern



- Drivers judged the sequential flashing light pattern to be easier to navigate; random flashing was judged most difficult to navigate
- Differences among flash patterns were larger at night, and were statistically significant only at night

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Results: Impact of Multiple Warning Light Intensity on Driver Responses

- Daytime
  - For ease of driving, accuracy of navigation and perceptions of how quickly subjects drove through the constriction, there were monotonically increasing relationships between the peak intensity of the multiple warning lights and each subjective response
- Nighttime
  - For each subjective response, the responses were highest when the peak intensity of the multiple warning lights was 25 cd and lower for other peak intensities
- Daytime/nighttime relationships with peak intensity were consistently ranked among all responses ($p<0.05$)

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Summary of Results

- A high-peak-intensity (750 cd) warning light at the start of an array of multiple lights is judged as glaring at night, but not during daytime
- Drivers prefer sequential to random flash patterns for multiple warning lights, especially at night
- During daytime, multiple warning lights with peak intensities up to 250 cd are judged as easier to drive through
- At night, a peak intensity of 25 cd is judged easiest to drive through

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